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Abstract

This paper examines the incentives of a vertically integrated firm to supply crude oil to an unintegrated downstream rival, using a stylized model based on the Brent market and UK oil taxation. Market analysts claim that crude oil trading by integrated firms is mainly tax–induced (*tax spinning*), thereby neglecting the effect of strategic interaction that induces vertical foreclosure in game–theoretical models. I show that in a two–stage game where the integrated firm moves first and the second stage is constituted by a Cournot game, the conditions behind vertical supply are more restrictive than the tax spinning hypothesis assumes.

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1 Introduction

In their review of *Models of the Oil Market*, Jacques Crémer and Djavad Salehi–Isfahani (1991) conclude that the next task of oil economists should be to apply techniques of strategic interaction that are now widely used in industrial economics. This request also implies the study of the industrial organization of oil markets with game–theoretic tools. This paper examines the incentives of a vertically integrated oil firm to supply crude oil to an unintegrated refining rival, which is completely dependent on the integrated firm's supply. Strategic interaction is invoked by duopolistic competition in the refining industry. There are powerful incentives for the integrated firm to cut off its crude oil supplies, i.e. to vertically foreclose its rival. By doing so it creates a second monopoly in the refining industry and earns the monopoly rent accruing to the vertical chain. The setting of this paper is based on a highly stylized abstraction from the *Brent market*. The market structure in the Brent market is oligopolistic, and one of its important features is the interaction of vertically integrated majors with unintegrated, independent firms. There is a widespread opinion among oil market analysts that crude oil trading by integrated oil companies is primarily motivated by the drive to minimise the companies' tax bill under the United Kingdom Continental Shelf (UKCS) tax regime.[1] The practice of selling a part of its crude oil production in the market and buying from it to satisfy remaining refining needs is known as tax spinning. However, the tax spinning hypothesis does not recognize the strategic impact vertical supply decisions have on the integrated firm's profit from its refining business. One of the major issues addressed in this paper is whether the tax spinning hypothesis survives the application of game–theoretic tools within a framework built upon partial integration and the UKCS tax regime. The model has two stages. The integrated firm acts first by committing to a crude oil price that it charges the un-

[1] A typical statement is the following quotation from the Weekly Petroleum Argus, a market analyst journal that refers to the major oil companies (Shell, BP, Exxon, Chevron, Texaco and Mobil) that are all "UK North Sea equity producers and use the market to balance their short term supply position and optimise their tax exposure" (WPA, 22 November, 1993).

integrated downstream rival. Crude oil production and crude oil refining are sequential stages. The extraction and transportation of wet barrels to the refining gates consumes time. This strengthens the credibility of the crude price commitment made by the integrated firm. In making its crude price decision, the integrated firm takes into account the output adjustment of its refining rival. The second stage is a Cournot game between the refiner and the integrated firm. The motivation to foreclose rivals is related to the concept of raising rivals cost, developed by Salop and Scheffman (1983, 1987) who claim that "vertical price squeezes can be viewed as conduct to raise rival's costs" (1983:268).

Vertical Foreclosure is a contested policy issue. Arguing in the tradition of the Chicago–School, Bork (1978), for example, claims that vertical mergers and vertical foreclosure do not have any anticompetitive impact and should be viewed from an efficiency perspective only. Vertical foreclosure has been explicitly addressed in a couple of recent papers using game–theoretic approaches. The conclusion of these papers is that a vertically integrated firm cuts off its supplies to downstream firms.[2] In a very interesting contribution, Spencer and Jones (1991) observe that, within an international trade policy setting, a tax on the export of the intermediate good encourages vertical supply. This result suggests that vertical foreclosure might depend on the concrete institutional setting. This insight is supported by the examination of the UK oil taxation regime. The conditions under which vertical supply or tax spinning can arise are, however, more restrictive than is claimed by the tax spinning hypothesis. A central role is played by the difference between the so–called tax price and the crude oil price at which foreclosure arises, the difference between the tax price and the refined products price, and the level of the Petroleum Revenue Tax–rate.

The next section describes the UKCS tax regime and develops the tax spinning hypothesis as discussed in the informal literature. Section 3 gives an outline of the model. The Cournot equilibrium in the refining industry and some useful comparative statics results are derived in section

[2]See Salinger (1988) and Ordover, Saloner and Salop (1990). Papers building upon the incomplete contract literature also demonstrate that market foreclosure can be an equilibrium phenomenon, see Hart and Tirole (1990), Bolton and Whinston (1991).

4. Section 5 deals with the optimal pricing decision of the integrated firm at the first stage and develops the conditions under which it will supply its rival with crude oil. Section 6 considers very recent changes in the UK tax system and its effects on vertical supply and tax spinning. Section 7 contains concluding remarks.

2 The Tax Regime in the UK Continental Shelf

2.1 The Institutional and Legal Framework

The oil taxation regime in the United Kingdom (UK) continental shelf is not neutral with respect to the behaviour of vertically integrated companies. The government imposes a special tax system on North Sea activities in order to recover part of the economic rent arising from the exploitation of oil fields. This system contains three elements:[3]

- royalties,
- the petroleum revenue tax (PRT), and
- the corporation tax (CT).

Royalties are levied in kind or cash and are treated as a cost item when the tax liabilities for PRT or CT are computed. The PRT is constructed as a *profit tax* levied oil field by oil field. The UK tax regime establishes a fiscal ring fence around every oil field for the PRT so that profits and losses incurred on one oil field cannot be compensated by profits or losses made on another field. A ring-fence around the *upstream activities* of integrated companies is established for CT-purposes, implying that losses arising downstream, i.e. in oil refining, products wholesaling and retailing, cannot be offset against upstream profits. The tax rates of the PRT and CT are constant, and there are very few elements of progression build into the tax base. Table 1 gives the series of nominal

[3]See Kay and King 1980, Mabro et al. 1986, Rowland and Hann 1987, Horsnell and Mabro 1993; a brief overview is given in a booklet issued by BP Exploration.

Year	CT-Rate	PRT-Rate	Upstream Rate
1975	52 %	45 %	73,6 %
1976	52 %	45 %	73,6 %
1977	52 %	45 %	73,6 %
1978	52 %	45 %	73,6 %
1979	52 %	60 %	80,8 %
1980	52 %	70 %	85,6 %
1981	52 %	70 %	85,6 %
1982	52 %	70 %	85,6 %
1983	50 %	75 %	87,5 %
1984	45 %	75 %	86,25 %
1985	40 %	75 %	85 %
1986	35 %	75 %	83,75 %
1987	35 %	75 %	83,75 %
1988	35 %	75 %	83,75 %
1989	35 %	75 %	83,75 %
1990	35 %	75 %	83,75 %
1991	35 %	75 %	83,75 %
1992	35 %	75 %	83,75 %
1993	35 %	50 %	67,5 %

Source: Rowland and Hann (1987), Favero (1991), Horsnell and Mabro (1993), own calculations

Table 1: **Oil Taxation in the UKCS, Nominal Rates 1975-1993**

PRT, CT and computed upstream tax rates for the period beginning with the implementation of the Oil Taxation Act 1975 until 1993. From 1975 through 1978, the PRT–rate was constantly set at 45%. In 1979, it rose sharply to 60%, while 1980 saw another increase of around 17% up to a level of 70%. The last increase came 1983 when the PRT–rate reached its historical peak with 75%, where it remained until March 1993 when the first decrease ever brought the rate down onto a level of 50%, thereby marking a sharp swing in Britain's tax policy towards the oil industry. Of special interest is the period 1978 to 1980 with a total increase in the PRT–rate of around 55% and the sudden reduction in 1993 of around one–third. The development of the CT–rate was much steadier. Beginning from a level of 52%, it saw a steady decline, furnished by tax policy committed to supply–side economics that started in 1983 and ended in 1986 when the CT–rate eventually hit its floor of 35%. The following two features of the oil fiscal regime are especially relevant for the behaviour of integrated firms on the intermediate good market.

Differential tax rates Profits incurred in the upstream division of a vertically integrated company are subject to both the PRT and CT, while downstream profits are taxed only according to CT. Independent of the actual tax rates of PRT and CT, the total tax rate on upstream activities is always higher than on downstream operations. The differential between the downstream rate, which is simply the CT–rate, and the computed *nominal* upstream tax–rate can be inferred from the information provided in Table 1.[4] Throughout the period considered, the upstream rate was *considerably* higher, reaching a peak of 87.5% in 1983. The difference between upstream and downstream taxes provide a powerful incentive for integrated oil companies to transfer as much profits as possible downstream to their refinery operations.

[4]The *effective* tax rate is, due to allowances, tax credits, etc. lower than the nominal rate. However, the latter is equal to the marginal rate, and since the analysis carried out in later sections is marginal analysis, the focus is on the nominal rate here. The various attempts to improve the advance of tax payments introduced by the government throughout the period under consideration as the Supplementary Petroleum Duty and the Advance Petroleum Revenue Tax are not taken into account. See Mabro et al. (1986) and Rowland and Hann (1987) for detailed accounts of these elements.

Valuation and tax spinning In order to obtain profit figures for PRT and CT purposes, the crude oil output must be valued. The valuation of crude oil production is based on market prices,

> that is (a) on price realized in the sale of the oil liable to tax in a genuine arm's length deal, or (b) on an assessment by the Oil Taxation Office of the market price of similar transactions when the oil liable to tax is appropriated by the producer, transferred or sold in a non-arm's length transaction (Horsnell and Mabro 1993:62).

To assign a value based on market prices for output disposed of through an internal transfer from upstream to downstream units of an integrated company, the UK Oil Taxation Office (OTO) has until 1984 considered the contemporary term price posted by the British National Oil Company (BNOC) as the artificial market reference price for such transactions.[5] In 1984, the BNOC term price was considered as no longer representative for the market, and in 1987 a new valuation method was introduced by OTO.[6] A vertically integrated company has the option to sell crude oil output to third parties through a market transaction (a so called "arm's length deal") or to transfer its crude oil output internally to its downstream unit. Mabro et al. (1986) and Horsnell and Mabro (1993) argue that the UK tax regime has a profound impact on the choice between these two options and is the main motivation behind a famous practice known as tax spinning. Tax spinning refers to a practice where an vertically integrated oil firm is selling a part of its crude oil output to the crude market ("third parties"), rather than transferring the output internally to its own refineries and satisfying its remaining refining needs for crude oil partly by purchases on the crude oil market.

[5] See section 5 for a discussion of the market reference price. BNOC was established in 1975 and existed until 1982 when its upstream operations were privatised. For the pricing and trading role of BNOC within the insitutional framework of the North Sea oil markets see Mabro et al. (1986).

[6] See section 6 for details.

2.2 Tax Parameters and Gains from Tax Spinning

There are three parameters set or defined by the tax authorities, the PRT-rate, the CT-rate and the tax-assessment price. It is assumed that transaction costs incurred by selling and buying crude oil on the market are negligible and therefore set equal to zero. I follow Mabro et al. (1986) to compute the tax liability of an integrated company from the two options available, internal use and market trade or spinning. The notation used in this paper is:

z		refined products price
c		constant marginal cost of crude oil production, constant internal transfer price
p		crude oil price
t_c		CT-rate, constant
t_p		PRT-rate, constant
p^a		tax (assessment) price for internal transfers
τ	$\equiv$	$(t_p + t_c - t_p t_c)$, total upstream tax rate
X		total refining industry output
θ		share of internally transferred crude oil of total integrated refining output
1		firm 1, unintegrated refiner
v		firm v, integrated firm
q		crude oil sales to firm 1 by firm v.

Internal transfer The tax liability T^i, other than royalties, from the internal transfer of a given amount of crude oil by the integrated firm is

$$T^i = (p^a - c)\, t_p + [(p^a - c)\cdot(1 - t_p)]\, t_c + (z - p^a)\, t_c.$$

The first term in this expression gives the PRT liability for upstream operations, where the tax authority has assessed a tax price p^a and crude oil production cost c are a deductible allowance against both PRT and CT. The second term gives CT liability of upstream operations, where the PRT liability is an allowance against CT. Finally, the third term represents the CT-liability of the integrated firm's downstream operations, where

the assessed purchase cost of crude oil p^a, is deducted from the tax bill (it is assumed, without loss of generality, that the cost of transforming crude oil into refined products is constant and equal to zero). The term $(z - p^a)\, t_c$ is only relevant if it is positive, since due to the fiscal ring-fence, a downstream loss cannot be set against upstream profits.[7] This expression reduces to

$$T^i = (p^a - c)\, \tau + (z - p^a)\, t_c, \tag{1}$$

where $\tau = (t_p + t_c - t_p t_c)$ is the upstream tax rate. Until the middle of the 1980s, the Oil Taxation Office determined p^a by using the term price posted by the British National Oil Company (BNOC) as the relevant tax price.

Tax Spinning The tax liability T^s, again without taking royalties into account, of selling the amount of crude oil to a third party on the crude oil market and buying the crude amount necessary to run the refining operations from another party is

$$T^s = (p - c)\, \tau + \underbrace{(z - p)\, t_c}_{\geq 0}. \tag{2}$$

Compared with (1), the tax-assessment price is replaced in (2) by the crude oil price p realized in a market deal.

The difference in tax liabilities from both options is given by subtracting (2) from (1) :

$$T^i - T^s = (p^a - p)\, (1 - t_c)\, t_p. \tag{3}$$

Equation (3) shows that tax spinning is the tax-optimal option for given PRT and CT- rates if $p < p^a$, since in this case the difference in (3) is positive, implying a *higher tax liability* for the internal disposal of a given barrel of crude oil. If the tax price exceeds the market price for a barrel of crude oil to be disposed, tax spinning results in a lower tax liability, independent of the values of the PRT-rate and CT-rate.

[7] In the analysis that follows, it is always ensured that refinery operations make a non-negative profit.

Mabro et al. (1986) claim that, from equation (3), the condition $p < p^a$ amounts to "the only necessary condition for a pure tax gain to arise from spinning" against internal transfers. If it is assumed that transaction costs were negligible,[8] the condition $p < p^a$ logically becomes the "only necessary" condition for an overall economic gain from tax spinning. They argue that the "simple economics of tax spinning is such as to make the practice almost irresistible" (1986:126) and provide detailed information about seven distinct periods during which there was a differential between the tax-price and the market price for Brent and which saw an increase in third-party sales by the integrated companies on the Brent market. The claim that $p < p^a$ is the necessary and sufficient condition for spinning to be profitable, constitutes the core of the tax spinning hypothesis. Moreover, there is a widespread view that tax spinning is not only the major explanation for the trading activity of integrated oil firms, but also for the emergence of the rather sophisticated spot and forward markets for Brent blend.[9]

3 Vertical Foreclosure: The Model

The basic setting of the model follows Spencer and Jones (1991) who analyse vertical foreclosure in an international trade policy framework. There are three players, two firms and a government that chooses the tax parameters. The vertically integrated oil firm, labelled v, refines crude oil products in competition with a non-integrated downstream rival, firm 1. Firm v is a monopolist on the crude oil market and potentially supplies part of its crude oil production externally to firm 1. It is assumed that firm 1 has no possibility to acquire the necessary crude oil input from other sources. Neither can firm 1 integrate backward and produce crude oil itself. It is thus locked into the vertical supply relationship with

[8] If transaction costs exists, Mabro et al. (1986) show that for "an overall pure gain to arise" (meaning an economic profit from spinning), the condition $p^a - p > \frac{\text{transaction costs}}{t_p}$ must be met. They argue that a small difference between the tax-assessment price and the market price is sufficient to create an economic gain from tax spinning.

[9] See also, for example, Clubley (1990).

the integrated major v. This assumption is introduced to make vertical foreclosure as easy or tempting as possible for the vertically integrated firm to analyse whether even in this extreme setting, vertical supply can arise. Assuming that the independent refiner is totally dependent on the major's crude supplies makes it a most simple exercise for the major to establish a second monopoly in the refining industry by pricing its potential crude oil supply so high that the independent firm exits the market. Moreover, this foreclosure incentive provides a useful benchmark to compare this solution with the equilibrium under the tax system. The assumption that there is a monopolist has further implications for the tax treatment of firm v's internal transfers.

Technology is represented by fixed-coefficients, and one unit of crude oil is required to produce one unit of refined products. Crude oil is considered to be the only input into the refining process. The cost of transforming crude oil into refined products is assumed to be zero, without loss of generality. Firm v produces crude oil at a constant marginal cost c which is also equal to the internal transfer price at which crude oil is transferred from v's upstream to its downstream units. Hence, v refines at marginal cost c, whereas firm 1 has to pay the market price p to obtain crude oil. Since p is monopolistically set by v, it will never be less than c, so there is an asymmetry in downstream costs.

The model is a two-stage game with complete information. The equilibria of each stage are required to be subgame-perfect in the sense of Selten (1975) and are solved recursively. In the first stage, firm v chooses a price p at which it sells crude oil to firm 1, taking the stage 2-equilibrium into account. The announcement of price p is a credible commitment, given the perfectness of the equilibrium of this subgame. The stage 2-subgame is a duopoly game where both firms v and 1 compete in quantities of refined products and the Nash-Cournot equilibrium is non-cooperative.

There is a difference between the concepts of *vertical supply, vertical foreclosure,* and *tax spinning. Vertical foreclosure* is given when the integrated firm charges a crude oil price, $\widehat{p}$, at which the independent firm chooses to produce nothing, i.e. it shuts its refinery down and exits the

market. Roughly, this situation is given whenever the refinery netback becomes negative, $z < p$.[10] Note that a change of the intermediate good price has an impact on the condition under which the refining industry operates, and hence on z. By increasing p, the major increases the independent firm's input cost, while its own cost function is unaffected. An increase in p induces firm 1 to cut back its output, while it induces the integrated firm to increase its output. These effects are made explicit in section 5. Suffice it to say that the final good price z shifts upward when the major increases the crude oil price. Thus, to make the difference $z - p$ negative, the major has to increase the crude price more than the products price z increases as a response to the increase in p.

Pure *vertical supply* but without tax spinning, is given when the vertically integrated firm charges a crude oil price at which the independent firm wants to produce a positive amount in the refined products market, $p < \widehat{p}$. There are, in addition to internal transfers, strictly positive external sales by the major. The difference between pure vertical supply and *vertical supply with tax spinning* is that in the spinning case the integrated firm v also *purchases* crude oil in the open market for tax reasons. The integrated oil firm is at the same time the sole seller and one of two buyers of crude oil, while the netback is favourable enough for the independent firm to produce a strictly positive output and demand a strictly positive crude oil input.[11]

The advocates of the tax spinning hypothesis neglect the impact of strategic interaction that inevitably is connected with the decision to use the crude oil market as an instrument for tax optimisation practices. Bulow, Geanakoplos and Klemperer observe that "changes in a firm's opportunities in one market may affect its profits by influencing its competitors' (or potential competitors') strategies in a second market (1985:488-9)".

[10] Since crude processing and transport costs are assumed to be zero, the netback is given by the difference between the products price z and the crude oil price p.

[11] I model crude oil as standard, renewable commodity. The introduction of a depletion constraint in the fashion of Hotelling (1931) and the resulting scarcity rent cannot explain current world oil prices (see Adelman 1986). Crémer and Salehi–Isfahani (1991) even count the irrelevance of exhaustibility as a basic building block of the emerging consensus about adequate models of oil markets.

An integrated oil firm does not set after–tax marginal revenue equal to after–tax marginal cost if its crude oil market actions when it foresees the effect any of its upstream decisions has on its rival's actions and thus on its own profits from refining operations. In other words, it considers the *strategic effect* its action on the crude oil market has on its profits from refining. In section 5, this strategic effect is made explicit.

4 Cournot Equilibrium in the Refining Industry

The price z of the final good output is given by the inverse demand function $z = z(X)$,where z is downward sloping, $z'(X) < 0$, and $X = x^1 + x^v$ represents total downstream output of refined products, and x^1 and x^v denote final good output by the non-integrated firm 1 and the integrated firm v, respectively.[12] Each of the rivals would prefer to produce a small amount of refined output if it were a monopoly in this market, $z(0) > \max\ [p, c]$ [13].The pre-tax profit of firm 1 is the difference between total revenue and cost, and this profit is taxed at the constant CRT-rate t_c.After-tax profit is given by

$$\Pi^1 = \left(z(X)x^1 - px^1\right)(1 - t_c)\,. \tag{4}$$

The construction of firm v's profit function is more involved. First, the pre-tax profit from refining and crude oil production is,

$$\Pi^v = z(X)x^v + p\ q - c\,[x^v + q]\,. \tag{5}$$

The first term on the right-hand side in (5) represents revenue from selling total refined output, the next term gives total revenue from selling crude oil production to the independent downstream rival 1, and the third term represents the total cost of crude oil production, where x^v is internally allocated and q is sold on the external crude oil market. Let (5) be augmented by the profit arising from a transaction comprising external sales

[12] A prime denotes a total derivative, and subscripts denote partial derivatives.

[13] It is, however, safe to assume that $p \geq c$.

of crude oil by the upstream unit, followed by a compensatory purchase of these sales by the downstream unit. Denote by $x^{v,i}$ refined products output produced by using internally transferred crude oil, and by $x^{v,e}$ output produced by purchasing the crude requirements via the crude oil market. Then (5) becomes

$$\Pi^v = [z(X) - c]\, x^{v,i} + [p - c]\, q + [z(X) - p]\, x^{v,e} + [p - c]\, x^{v,e}, \quad (6)$$

where $(p - c)x^{v,e}$ is the upstream revenue from selling crude oil to the downstream unit. Note that total crude oil sales are given by $q + x^{v,e}$, and crude oil production by $q + x^{v,e} + x^{v,i}$. Consolidating up- and downstream profits in (6) gives $[z(X) - c]\, x^{v,e}$, and by using the identity $x^{v,i} + x^{v,e} \equiv x^v$, this leads back to equation (5). In the absence of costs of using the crude oil market, the integrated firm's profit is not affected whether oil is sold externally on the market and purchased back externally, or channeled internally from v's producing to its refining operations. If, however, there were the slightest transaction cost involved, and much of the literature on vertical integration refers to transaction cost as a motivation for integrated production, internal transfers become the cost–minimising option.[14]

If the integrated firm operates under the tax regime in the UK, a simple consolidation of external sales and purchases in one profit expression is no longer possible, and the equivalence between external transactions and internal transfers breaks down. The UK oil tax regime drives a wedge between the different strategies of transferring crude oil from the integrated firm's production to its refining stage. Rewriting (6) to take account of the tax-regime yields

$$\begin{aligned}\Pi^v = {} & [z(X) - c - (z(X) - p^a)\, t_c - (p^a - c)\, \tau]\, x^{v,i} + [(p - c)\,(1 - \tau)]\, q \\ & + [(z(X) - p)\,(1 - t_c)]\, x^{v,e} + [(p - c)\,(1 - \tau)]\, x^{v,e},\end{aligned} \quad (7)$$

As in (6), the identity $\mathrm{x}^{v,i} + x^{v,e} \equiv x^v$ also holds in (7). Since it makes one of the variables involved redundant, it is possible to redefine the variables as follows: $x^{v,i} \equiv \theta x^v$, $x^{v,e} \equiv (1 - \theta)x^v$, where θ represents

[14]This, however, assumes that the cost of carrying out the transfer within the integrated firm are at least smaller than the external transaction cost.

the share, given the total downstream production of refined products by v, of internally transferred and refined crude oil, and $(1 - \theta)$ represents the share of crude oil bought on the external market and subsequently refined. θ assumes a determined value for the marginal cases where (i) all refining needs are satisfied by internal transfers ($\theta = 1$) or (ii) where all refining needs are satisfied by purchases on the external market ($\theta = 0$). For the hybrid cases, θ will be in the interval $0 < \theta < 1$. The tax system imposes an important restriction upon θ. The Oil Taxation Office accepts only those market transactions establishing a market price for the crude oil liable to tax that fulfill certain conditions:

> (T)he deal must qualify as 'arm's length' by fulfilling all the following conditions: (a) the contract price is the sole consideration for the sale; (b) the sale is between unconnected parties; (c) neither the seller (nor any person connected) has any interest in the subsequent resale of oil or any produce derived from it (Horsnell and Mabro 1993, p. 62).

Thus, according to (b), deals between subsidiaries of the same company, such as between the upstream and downstream division of an integrated firm, do not qualify as arm's length. Since there is only *one* upstream producer, this condition could never be fulfilled. To get around this point, it is therefore assumed that if there were only one producer upstream, the OTO would suspend condition (b) provided, however, that there is at least one other unconnected party that is also an *active* buyer in the crude oil market. One might think of this argument in terms of the anonymity the Brent market provides to disconnect the deals made between the upstream and downstream departments of integrated firm. Horsnell and Mabro (1993) even argue that the need to separate a tax–motivated oil sale from a compensatory purchase by mingling them together with other genuine third–party deals is partly responsible for the birth of the Brent market. This market separation advantage disappears once the independent rival firm 1 is foreclosed from the crude oil market, i.e. his crude oil demand is reduced to zero. Then, the OTO would find it impossible to deny any connection between the integrated firm's upstream and downstream divisions that remain the sole seller and buyer on

the market and would therefore not accept any such transaction as being arm's length. Since this removes the fiscal motivation for purchases of crude requirements on the external market for v, and since it was argued above that there are no other incentives for external transactions at work, vertical foreclosure implies that all crude requirements are transferred internally, i.e. for the foreclosure case $\theta = 1$.

Recall that x^v is *not* equal to total upstream production of crude oil, since the potential external sales to the rival firm 1, q, have to be taken into account. Then, the identity becomes

$$x^v \equiv \theta x^v + (1-\theta)x^v,$$

and (7) can be rewritten to yield

$$\begin{aligned} \Pi^v = \theta\, x^v \left[z(X) - c - (z(X) - p^a)\, t_c - (p^a - c)\, \tau\right] \\ +(1-\theta)x^v \left[(z(X) - p)\,(1 - t_c) + (p - c)\,(1 - \tau)\right] \\ +\left[(p - c)\,(1 - \tau)\right] q. \end{aligned} \tag{8}$$

The bracketed expression in the first line of the right-hand side of (8) gives the after tax profit from internally transferring, refining and selling the amount of crude oil. The first term in the bracket, $z(X) - c$, gives the pre-tax economic profit from selling crude oil which was *internally bought* at transfer price c. Due to the internal character of this transaction, the tax authority imposes a downstream tax payment of $(z - p^a)t_c$, where the taxation office imputes a tax price p^a for this transaction. The same tax price is used to compute the upstream tax liability $(p^a - c)\tau$. The first term in the bracket in the second line of (8) gives the downstream unit's after-tax profit from selling refined products for which the crude oil requirements were bought at price p on the external market. This corresponds to the profit from internally transferred oil, with the exception that now the tax office takes the market price as the tax price for assessing the tax liability. The second term in the bracket in the second line gives the upstream after-tax profit figure from crude oil sales to the downstream unit of v, where, again, the tax price equals the realized market price. Finally, the term in the third line of (8) gives the after-tax profit from sales to rival firm 1. Multiplying out (8) and collecting terms

gives

$$\Pi^v = x^v \left[z(X) - c - (z(X) - p)\, t_c - (p - c)\, \tau\right] + \left[(p - c)\,(1 - \tau)\right] q \\ - \theta\, x^v \left[(p^a - p)\, \underbrace{(t_p(1 - t_c))}_{=(\tau - t_c)}\right]. \tag{9}$$

The first term on the right-hand side of (9) shows after tax-profit from sales of refined products, taxed as if these were transformed by using only internally transferred crude oil, the second term represents profits from sales of crude oil to firm 1. The third term in (9) is, when $\theta > 0$, negative for $p^a > p$, positive for $p^a < p$, and becomes zero for $\theta = 0$. Hence, if the tax-price exceeds the market price, this difference, taxed at the differential of up- and downstream taxes $(\tau - t_c) = (t_p(1 - t_c))$ and multiplied by the amount of internally transferred oil, contributes negatively to the total after-tax profit. In this case, since the tax price for internal transactions p^a is higher than the tax price for external transactions p, this expression provides a tax punishment of internal transfer. If, on the other hand, the difference $(\mathrm{p}^a - p)$ is negative, there is a tax reward for internal transfers. Finally, if in (9) the tax parameters t_c and t_p are set equal to zero, (9) reduces to equation (5).

Firms 1 and v set their quantities to maximise their profits (4) and (9) given the value of p to which the integrated firm has itself committed in its production stage-1 choice of p, and the tax-parameters t_c, t_p, and p^a. The first-order conditions are

$$\Pi_1^1 = \left(z + x^1 z' - p\right)(1 - t_c) = 0 \quad \Leftrightarrow \quad z + x^1 z' - p = 0 \tag{10}$$

and

$$\Pi_v^v = \mu + x^v z'(1 - t_c) - \theta\left[(p^a - p)\,(t_p(1 - t_c))\right] = 0, \tag{11}$$

where $\mu \equiv (z - c - (z - p)\, t_c - (p - c)\, \tau)$. The corresponding second-order conditions are

$$\Pi_{11}^1 = 2z' + x^1 z'' \tag{12}$$

and

$$\begin{aligned} \Pi_{vv}^v &= \mu_v + (1 - t_c) z' + x^v z''(1 - t_c) \\ &= (1 - t_c)\,(2z' + x^v z''). \end{aligned} \tag{13}$$

The second-order conditions for a global maximum are $\Pi^i_{ii} < 0$, $i = 1, v$. The Cournot equilibrium is the set of self–enforcing actions in the quantity space from which neither firm 1 nor firm v would individually want to deviate. It is found as the simultaneous solution to (10) and (11):

$$x^1 = x^1(p, t_c, t_p, p^a), \quad x^v = x^v(p, t_c, t_p, p^a). \tag{14}$$

The Cournot equilibrium strategies depend on the crude price p that is charges in stage 1 and the tax parameters t_p, t_c and p^a that are set before the crude oil market meets. To perform comparative statics, the existence, stability, and uniqueness of the Cournot equilibrium must be ensured.

Existence is ensured if the profit functions for firm 1 and firm v are concave in its own output. Since marginal cost for firm 1 and firm v are constant, it is sufficient for concavity of each firm's profit function that the final demand $z(X)$ function be concave, $z'' \leq 0$. To ensure that the reaction functions of firm 1 and firm v intersect, I shall assume the following additional technicality: $R^{j-1}(0) > R^i(0) = x^{i,m}$, where R^i is i's reaction function, $i, j = 1, v$, $i \neq j$. This assumption implies that firm i's output that induces firm j to produce nothing exceeds i's monopoly output $x^{i,m}$.

A sufficient condition for uniqueness of (14) is that the derivative of the reaction functions be less than 1 in absolute value. The reaction function R^i, $i = 1, v$, is implicitly defined by the first-order conditions (10) and (11). The slope of the reaction functions is found by the implicit function theorem,

$$R^{i\prime} \equiv \frac{dx^i}{dx^j} = -\frac{\Pi^i_{ij}}{\Pi^i_{ii}}, \quad i, j = 1, v, \quad i \neq j. \tag{15}$$

From (15), $|R^{i\prime}| < 1$ if $|\Pi^i_{ii}| > \left|\Pi^i_{ij}\right|$. Differentiating the first–order conditions (10) and (11) with respect to the respective rival's output yields $\Pi^1_{1v} = z' + x^1 z'' < 0$ and $\Pi^v_{v1} = \mu_1 + x^v z''(1 - t_c) = (1 - t_c)(z' + x^v z'') < 0$. Uniqueness, i.e. $|R^{i\prime}| < 1$ is then equivalent to $|z'| > 0$.

Following Dixit (1986), the stability conditions require

$$\Pi^1_{11} < 0, \quad \Pi^v_{vv} < 0, \quad \Omega \equiv \Pi^1_{11}\Pi^v_{vv} - \Pi^1_{1v}\Pi^v_{v1} > 0. \tag{16}$$

The second-order conditions (12) and (13) can be subsumed under the stability conditions (16).[15]

Totally differentiating the first-order conditions (10) and (11) yields

$$\begin{array}{rcrcrcl} \Pi^1_{11}dx^1 & + & \Pi^1_{1v}dx^v & + & \Pi^1_{1\iota}d\iota & \equiv & 0 \\ \Pi^v_{v1}dx^1 & + & \Pi^v_{vv}dx^v & + & \Pi^v_{v\iota}d\iota & \equiv & 0 \end{array}, \tag{17}$$

where ι stands for either p, t_c, t_p or p^a. In matrix notation,

$$\begin{pmatrix} \Pi^1_{11} & \Pi^1_{1v} \\ \Pi^v_{v1} & \Pi^v_{vv} \end{pmatrix} \begin{pmatrix} dx^1 \\ dx^v \end{pmatrix} = - \begin{pmatrix} \Pi^1_{1\iota}d\iota \\ \Pi^v_{v\iota}d\iota \end{pmatrix}.$$

The solution to this system is given by

$$\begin{pmatrix} dx^1 \\ dx^v \end{pmatrix} = -\frac{1}{\Omega} \begin{pmatrix} \Pi^v_{vv} & \Pi^1_{1v} \\ \Pi^v_{v1} & \Pi^1_{11} \end{pmatrix} \begin{pmatrix} \Pi^1_{1\iota}d\iota \\ \Pi^v_{v\iota}d\iota \end{pmatrix}. \tag{18}$$

From (18), (10) and (11), the comparative static effects of an increase in the crude oil price p are

$$\frac{dx^1}{dp} \equiv x^1_p = \frac{1}{\Omega} \left[\Pi^v_{vv} \underbrace{-\Pi^1_{1v}\left(1-\theta\right)\left(t_p(1-t_c)\right)}_{(+)} \right] < 0 \quad \text{for} \quad \theta = 1, \tag{19}$$

and

$$\frac{dx^v}{dp} \equiv x^v_p = \frac{1}{\Omega} \left[-\Pi^v_{v1} \underbrace{+\Pi^1_{11}\left(1-\theta\right)\left(t_p(1-t_c)\right)}_{(-)} \right] > 0 \quad \text{for} \quad \theta = 1. \tag{20}$$

From (19) and (20), an increase in p lowers firm 1's equilibrium refined output and raises firm v's unambiguously only if $\theta = 1$. In this case, by driving p up in stage 1 and thereby raising its rivals cost, the integrated firm has a powerful tool to reduce its competitor's output on the refined products market and potentially to install a monopoly. If the integrated firm sells a positive amount of crude oil to its own downstream unit, a counter effect comes into play that dampens firm 1's output decrease and firm v's output increase. The total effect depends on the relative

[15]This is not a general result and holds only for the case of Cournot duopoly.

strength of these counteracting effects, and cannot be signed generally. However, the incentive to raise its rivals' cost is weaker (i) in the presence of taxation than in the no-tax case, since for $t_c = t_p = 0$, the counter effect in (19) and (20) reduces to zero, and (ii) in the case of sales to its own subsidiary. If the counter effect becomes strong enough, the integrated firm might even find reducing rival's cost by setting p very low a profitable strategy.

The total industry output is decreasing in p,

$$X_p = \left(\frac{dx^1}{dp} + \frac{dx^v}{dp}\right) = \frac{z'}{\Omega}\left[(1-t_c) + (1-\theta)\left(t_p(1-t_c)\right)\right] < 0. \qquad (21)$$

implying that the final products price z is increasing in p, $z'X_p > 0$. A change in p induces two counteracting effects on the equilibrium response of total refining output, where the quantity decreasing effect caused by firm 1's equilibrium reaction is stronger than the induced expansion of v's output.

Similarly, an increase in the corporation tax rate t_c has ambiguous effects as well,

$$\frac{dx^1}{dt_c} \equiv x^1_{t_c} = \frac{1}{\Omega}\left[\Pi^1_{1v}\left(t_p\left((\theta p^a - c) + (p(1-\theta))\right) - (z + x^v z' - c)\right)\right], \qquad (22)$$

$$\frac{dx^v}{dt_c} \equiv x^v_{t_c} = \frac{1}{\Omega}\left[-\Pi^1_{11}\left(t_p\left((\theta p^a - c) + (p(1-\theta))\right) - (z + x^v z' - c)\right)\right]. \qquad (23)$$

Imagine for a moment a PRT-rate t_p of zero. Then, by (22) an increase of the CRT-rate would serve to decrease x^1. The effect on x^v remains ambiguous and depends on the relative strength of -Π^1_{11} and $-(z + x^v z' - c)$, see (23). The comparative static effects of a change in t_p are

$$\frac{dx^1}{dt_p} \equiv x^1_{t_p} = \frac{1}{\Omega}\left[-\Pi^1_{1v}(1-t_c)\left((1-\theta)p + (\theta\ p^a - c)\right)\right], \qquad (24)$$

and

$$\frac{dx^v}{dt_p} \equiv x^v_{t_p} = \frac{1}{\Omega}\left[\Pi^1_{11}(1-t_c)\left((1-\theta)p + (\theta\ p^a - c)\right)\right]. \qquad (25)$$

It was argued in section 3 that it is plausible to assume $p^a > c$. Then, the term $(\theta\ p^a - c)$ is positive for $\theta = 1$, and changes sign at some value of θ,

	$\iota = p$	$\iota = t_c$	$\iota = t_p$	$\iota = p^a$
$dx^1/d\iota$	$-$	$+/-$	$+$	$+$
$dx^v/d\iota$	$+$	$+/-$	$-$	$-$

Table 2: **Comparative Statics for** $\theta = 1$

$\widehat{\theta}$ say, such that $0 \leq \widehat{\theta} < 1$. Hence, for $\theta > \widehat{\theta}$, (24) has unambiguously a positive, and (25) exhibits unambiguously a negative sign. The effect of a change in the tax price p^a on the Cournot equilibrium refined outputs of firms 1 and v is:

$$\frac{dx^1}{dp^a} \equiv x^1_{p^a} = \frac{1}{\Omega}\left[-\Pi^1_{1v}\theta\ t_p(1-t_c)\right] \geq 0 \quad \text{if} \quad \theta \geq 0, \tag{26}$$

$$\frac{dx^v}{dp^a} \equiv x^v_{p^a} = \frac{1}{\Omega}\left[\Pi^1_{11}\theta\ t_p(1-t_c)\right] \leq 0 \quad \text{if} \quad \theta \geq 0. \tag{27}$$

An increase in p^a serves to increase firm 1's output, and decreases firm v's output, as long as $\theta > 0$. These results are intuitively appealing: A higher tax price serves as an *asymmetric* cost increase affecting only the integrated firm as long as some crude oil is transferred internally. The comparative statics results of equations (19) through (27) are summarized in Table 2 for $\theta = 1$, which is a condition that becomes important in section 5.

Suppose that the integrated firm's output $x^v(p, t_c, t_p, p^a)$ is fixed at its Cournot equilibrium level. What would the effect of an increase in firm 1's output be on the profit of the integrated firm v. To derive this effect, the following function Υ is defined as

$$\begin{aligned}\Upsilon(p, t_c, t_p, p^a) &\equiv \Pi^v_1(p, t_c, t_p, p^a) \\ &= \theta\left[(p^a - p)\left(t_p(1-t_c)\right)\right] - (1-t_c)\,(z-p)\,,\end{aligned} \tag{28}$$

where (11) was used to substitute for x^v. Rewriting (28),

$$\begin{aligned}\Upsilon(p, t_c, t_p, p^a) = [(p-c) - (z-c)] + (z-p)\,t_c \\ +\theta\left[(p^a - p)\left(t_p(1-t_c)\right)\right].\end{aligned} \tag{29}$$

With the formulation of equation (29), Υ has a special meaning: The first bracketed term on the right hand side is the difference in profit margins

from sales of crude oil and refined products, respectively. In the absence of taxation, (29) becomes $\Upsilon(p) = (p - c) - (z - c)$, and an increase in firm 1's output, given that v's output remains at the noncooperative equilibrium level, increases v's profit if and only if the profit margin from crude oil sales is greater than from refined product sales, or $p > z$. Under the UK oil fiscal system, this simple rule breaks down. Suppose that $p^a = p$. Then, from (29), the integrated firms' equilibrium profit increases in x^1 if $(p - z)(1 - t_c) > 0$, or $(p - z) > 0$. Hence, the existence of a CT makes no difference as long as the tax price equals the crude oil price. If $p^a > p$, the requirement that $(p - c) - (z - c) > 0$ for $\Upsilon > 0$ is relaxed, and if $p^a < p$, it is severed. Hence, the tax price-crude oil price differential exercises influence on the reaction of v's profit on a change in x^1.

5 The Crude Oil Market: Equilibrium Vertical Foreclosure Versus Supply

The crude oil market forms the first stage of the game. The integrated firm's strategy set consists of the crude oil price p it charges its downstream rival 1.[16] It is optimising on a derived demand function which is implied by fixed-coefficients technology. Since firm v foresees the effect its crude pricing action has on the revenue from its refining undertakings, its profit can be written as a function of p, t_c, t_p, and p^a :

$$\begin{aligned}\Pi^v(p, t_c, t_p, p^a) = {} & x^v(p, t_c, t_p, p^a)\ \mu(p, t_c, t_p, p^a) \\ & -\theta\ x^v(p, t_c, t_p, p^a)\left[(p^a - p)\,(t_p(1 - t_c))\right] \\ & +(p - c)\,(1 - \tau)\,q\,(p, t_c, t_p, p^a)\,.\end{aligned} \tag{30}$$

[16] θ, being a further potential decision variable, is subject to certain constraints set by the OTO's policy not to accept back–to–back deals. Since the remainder of section 5 is built around v's conduct around the foreclosure point, the constraint imposed by the tax authorities become binding and θ will be equal to 1.

The integrated firm's problem is to pick a price p such that

$$\begin{array}{rccc} & p \in \arg\max \Pi^v(p, t_c, t_p, p^a) & & \\ & (i) \quad q(p, t_c, t_p, p^a) & \geq & 0 \\ \text{s.t.} & (ii) \quad x^1(\cdot) & = & q(\cdot) \\ & (iii) \quad \theta & \in & [0,1]\,. \end{array} \tag{31}$$

In (31), the first constraint ensures that firm 1's input demand cannot become negative. The second constraint is dictated by the fixed–coefficients technology, while the third is a consistency requirement. To find the p that maximises (31) write the Lagrangian $\mathcal{L} = \Pi^v(p, t_c, t_p, p^a) + \lambda q(p, t_c, t_p, p^a)$ (it is ensured that constraints (ii) and (iii) are always satisfied). The Kuhn–Tucker conditions are

$$\begin{array}{c} \mathcal{L}_p = \Pi^v_p(p, t_c, t_p, p^a) + \lambda q_p(p, t_c, t_p, p^a) = 0 \\ \mathcal{L}_\lambda = q(p, t_c, t_p, p^a) \geq 0, \quad \lambda \geq 0, \quad \mathcal{L}_\lambda \lambda = 0. \end{array} \tag{32}$$

Consider the first–order condition at a *vertical supply equilibrium*, i.e. $\lambda = 0$. From (30), using (11),[17]

$$\begin{array}{c} \Pi^v_p = (1-\tau)\left((p-c)q_p + q\right) \\ +x^v\left[(1-t_c)\, z'\; x^1_p\right] - \underbrace{(1-\theta)x^v\left(t_p(1-t_c)\right)}_{\text{Pure Tax effect}} = 0. \end{array} \tag{33}$$

Before discussing (33), consider the second–order condition for a maximum of (31). For all $p \leq \widehat{p}$, I assume that $\Pi^v(\cdot)$ is strictly concave, where $\widehat{p}$ is defined by $q(\widehat{p}, t_c, t_p, p^a) = 0$ and $\theta = 1$. For linear final good demand, the second–order condition becomes[18]

$$\Pi^v_{pp} = \frac{2}{9}(1-t_c)z'^{-1}\left\{t_p\left(t_p\left(\theta\left(5-4\theta\right)-1\right)-\theta\right)+5\left(1-t_p\right)\right\} < 0. \tag{34}$$

For $\theta = 0$, $\Pi^v_{pp} < 0$ for $t_p < 0.854$, and for $\theta = 1$, $\Pi^v_{pp} < 0$ for $t_p < 5/6$. For any $\theta \in (0,1)$, the negative sign of (34) is preserved as long as $t_p < 0.854$. Hence, $\Pi^v_{pp} < 0$ is ensured for all $\theta \in [0,1]$ if $t_p < 5/6$. The requirement

[17] For brevity's sake, I shall omitt the explicitly written functional dependence of the variables, except when a variable is evaluated at the foreclosure price $\widehat{p}$.

[18] Note that for linear demand $z'' = 0$ and $\Omega = 3(1-t_c)z'^2 > 0$.

$t_p < 5/6$ was met ever since the current tax regime came into effect, see Table 1.

For the benchmark case without a tax system first, (33) takes the following form

$$\Pi_p^v = \underbrace{(p-c)\,q_p + q}_{\text{Direct Effect}} + \underbrace{z'\,x_p^1\,x^v}_{\text{Strategic Effect}} = 0. \tag{35}$$

To facilitate an interpretation of (35), it is useful to notice the different effects identified in the literature of a change in a first–stage decision variable on firm v's profit.[19] First, the effect of p on Π^v through the integrated firm's refining stage choice $x^v(p)$ is only of *second–order* by applying the envelope theorem. Second, the *direct effect* of a change in p on v's profit would exists even if p would have no impact on firm 1's behaviour. Shapiro (1989) points out that this direct effect would be the only prevailing one in an open–loop equilibrium, where the integrated firm takes its refining rival's strategies as given in *both* stages.[20] In (35), the direct effect is simply net marginal revenue which is known from standard models of monopoly behaviour. Third, a *strategic effect* results from the influence of p on firm 1's first period action $x^1(p)$, which in turn influences firm v's profit. Quite generally, the strategic effect can be written as $\frac{\partial \Pi^v}{\partial x^1} x_p^1$. From (19), the sign of x_p^1 is known, which is negative for $\theta = 1$. Looking at (35), the strategic effect is unambiguously positive for $\theta = 1$, since in this case $z' < 0$, $x_p^1 < 0$, and $x^v > 0$, from which it follows that $\frac{\partial \Pi^v}{\partial x^1} < 0$. Compared with the closed–loop solution, the strategic effect prescribes that the integrated firm should "overprice" its crude oil output. If the strategic effect is sufficiently large, v charges a high p such that $q = 0$, which is the definition of firm 1 to be vertically *foreclosed*. Rewriting (35) yields a modification of the standard mark–up pricing rule for a monopoly,

$$\frac{p-c}{p} = \frac{1}{\epsilon} - \frac{z'x^v}{p}, \tag{36}$$

[19] See Bulow, Geanakoplos and Klemperer (1985), Fudenberg and Tirole (1984), and Tirole's (1988) textbook on industrial organisation, chapter 8.

[20] In a subgame–perfect equilibrium or closed–loop equilibrium, the integrated firm only takes its rival's action as given in refining (second) stage competition, but not when it considers its crude oil pricing (first stage) decisions.

where $\epsilon \equiv -q_p \frac{p}{q}$ denotes the derived demand elasticity and the second term on the right–hand side results from the strategic effect. For a positive vertical supply, the left-hand side of (36) must be greater than one. Even if v is operating on the elastic part of the derived demand function, it can be optimal for the integrated firm to foreclose the crude oil market if the strategic term on the right-hand side, $-\frac{z' x^v}{p} > 0$, is large enough to make $\frac{p-c}{p}$ approach one.

The first-order condition under taxation (33) shows that an *after-tax direct effect* and an *after-tax strategic term* are governing firm v's crude pricing choice, where the former is subject to the upstream rate τ, and the latter only to the downstream CRT-rate t_c. The third term in (33) represents a pure *tax effect* on Π^v because it has no precedent in (35). This tax effect becomes zero either if $t_p = 0$ or if $\theta = 1$. Rewriting (33) so as to make it comparable with (35) yields

$$\frac{p-c}{p} = \frac{1}{\epsilon} \underbrace{-\frac{z' x^v}{(1-t_p)\, p}}_{(>0 \text{ for } t_p>0)} + \overbrace{\frac{t_p}{1-t_p} \frac{(1-\theta)\, x^v}{q_p p}}^{(<0 \text{ for } t_p>0 \text{ and } \theta<1)} . \tag{37}$$

For $t_p > 0$ and $\theta < 1$, the tax effect is strictly negative. It therefore has a supply inducing influence on firm v's optimisation programme. In other words, as long as the integrated firm's downstream unit buys some barrels of crude oil on the open market and the PRT–rate is greater than zero, the "overpricing" influence emanating from the after–tax strategic effect is "diluted" by an amount proportional to the share of crude oil bought externally and to t_p.

The foreclosure price is implicitly defined by

$$q\left(\widehat{p}, t_c, t_p, p^a\right) = 0 \qquad \Rightarrow \qquad \widehat{p} = \widehat{p}(t_c, t_p, p^a) \quad \text{and} \quad \theta = 1. \tag{38}$$

Due to the OTO–rules regarding the non–acceptance of back–to–back deals for nomination, setting the crude oil price equal to $\widehat{p}$ has the further implication that θ will automatically be set equal to one.

Now consider (33) at $p = \widehat{p}$ and $\theta = 1$:

$$\Pi_p^v(\widehat{p}) = (1-\tau)\left((\widehat{p}-c)q_p\right) + x^v\left[(1-t_c)\, z'\, x_p^1\right]. \tag{39}$$

Following the approach introduced by Spencer and Jones (1991), (39) is rewritten, using (11), (29), $x_p^1 = q_p$, and $\theta = 1$:

$$\Pi_p^v(\widehat{p}) = \Upsilon(\widehat{p})\; q_p \tag{40}$$

Equation (40) is a very useful expression to derive explicit conditions for vertical supply or foreclosure. At the foreclosure price, a further increase in the crude oil price cannot increases firm v's profits, since the independent rival's derived demand is equal to zero at $\widehat{p}$. On the other hand, if a small reduction in the crude oil price results in an increase of $\Pi^v(\widehat{p})$, foreclosing firm 1 is not profit–maximising. Rather, it will set a price $p < \widehat{p}$ that corresponds to vertical supply. The integrated firm v engages in vertical supply if and only if a *reduction* in p below the foreclosure price $\widehat{p}$ *increases* v's profit (30). In other words, vertical supply is the equilibrium outcome if and only if

$$\Pi_p^v(\widehat{p}) = \Upsilon(\widehat{p})\; q_p < 0.$$

Due to the fixed-coefficients technology $q_p = x_p^1$, and by (19) q_p is negative if $\theta = 1$. Then, vertical supply is conditional on the sign of the after–tax profit–margin function Υ defined in (28). The following two cases are possible:

$$\Upsilon(\widehat{p}) \begin{cases} > & 0 \;\Rightarrow & \text{vertical supply} \\ \leq & 0 \;\Rightarrow & \text{vertical foreclosure} \end{cases}.$$

To establish a benchmark outcome, consider the *case without taxation* first.

Proposition 1 (Spencer and Jones 1991) *Suppose that there is no taxation, i.e.* $t_c = t_p = 0$. *Then the integrated oil producer-refiner* v *will vertically foreclose its downstream rival firm 1 from its own crude oil supply, thereby creating a (second) monopoly in the refining industry.*

Proof Setting $t_c = t_p = 0$, the condition for vertical supply can be written as

$$\Upsilon(\widehat{p}) = (\widehat{p} - c) - (z(\widehat{p}) - c) > 0 \quad \Leftrightarrow \quad \widehat{p} > z(\widehat{p}). \tag{41}$$

From (10), firm 1 produces the final good at $p = \widehat{p}$ if and only if the crude oil price $\widehat{p}$, representing marginal cost of the first unit of refined output, were below the price of refined products z which is the marginal revenue from selling the first unit of refined outputs. The condition $z > \widehat{p}$ is a contradiction of (41) and the integrated firm forecloses its downstream rival firm 1 from its crude oil supply.

This result is intuitive: The integrated firm has the leverage, by foreclosing its rival from its crude oil supplies, to create a second monopoly in refining. It is this monopolisation effect that drives the strategic effect that appears in (33) and (35). This result is perfectly in line with related observations in the game-theoretic literature.

To see whether the introduction of taxes change the nature of equilibrium, consider (29) at $\widehat{p}$:

$$\begin{aligned} \Upsilon(\widehat{p}) &= [(\widehat{p} - c) - (z - c)] + (z - \widehat{p})\, t_c + (p^a - \widehat{p})\, (t_p(1 - t_c)) \\ &= (p^a - \widehat{p})\, (t_p(1 - t_c)) - (1 - t_c)\, (z - \widehat{p})\,. \end{aligned} \tag{42}$$

In (37) *two* price differentials have to be considered by the integrated firm in its foreclosure versus supply decision. The first represents the difference between the officially assessed tax price and the foreclosure price for crude oil, taxed at $t_p(1 - t_c)$. The second is the after-tax difference between the foreclosure price for crude oil and the refined products price. Since p^a is set by the OTO and is thus determined exogenously, three cases can be distinguished, depending on the difference between p^a and $\widehat{p}$.

Case 1: $p^a = \widehat{p}$ This case arises when the tax authority sets the tax price exactly equal to the foreclosure price. Then, (37) reduces to $\Upsilon(\widehat{p}, p^a = \widehat{p}) = -(1 - t_c)\, (z - \widehat{p})$. This expression is positive if $(1 - t_c)\, (\widehat{p} - z) > 0$, or if $\widehat{p} > z$. By Proposition 1, the equilibrium in case 1 is that v will vertically foreclose the market.

Case 2: $p^a > \widehat{p}$ This constellation arises when the tax price exceeds the foreclosure price. Rewriting (37), the condition for vertical supply becomes

$$\Upsilon(\widehat{p}, p^a > \widehat{p}) > 0 \quad \Leftrightarrow (p^a - \widehat{p})\, t_p > z - \widehat{p} \quad . \tag{43}$$

From condition (38), $z - \widehat{p} > 0$, if there exists, for a given p^a, a $t_p > \widehat{t}_p$ where $\widehat{t}_p \equiv \frac{z-\widehat{p}}{p^a-\widehat{p}}$ is defined as the PRT-rate at which foreclosure is the equilibrium.

Case 3: $p^a < \widehat{p}$ If the tax price is set *below* the foreclosure price, (37) becomes

$$\Upsilon(\widehat{p}, p^a < \widehat{p}) > 0 \quad \Leftrightarrow \quad (\widehat{p} - p^a)\, t_p < (\widehat{p} - z)\,, \tag{44}$$

and for vertical supply to be an equilibrium, $(\widehat{p} - z) > 0$ since $(\widehat{p} - p^a) > 0$ and $t_p > 0$. Hence, for case 3, foreclosure is the resultant equilibrium. These results are summarized in Proposition 2.

Proposition 2 *The variables and magnitudes affecting the supply equilibrium are the relationship between p^a, z and $\widehat{p}$, as well as the PRT-rate t_p. Depending on the relationship between p^a and p, the following cases can be distinguished:*

1. *For $p^a \leq \widehat{p}$, the integrated firm v forecloses its independent rival, independently of t_p.*

2. *Necessary for vertical supply to arise is the condition $p^a > \widehat{p}$. Due to the constraint $0 \leq t_p \leq 1$, there two sufficient conditions for vertical supply: $z < p^a$ and $t_p > \widehat{t}_p \equiv \frac{z-\widehat{p}}{p^a-\widehat{p}}$. Hence, $\widehat{p} < z < p^a$ must hold with strict inequalities in a supply equilibrium. Otherwise, vertical foreclosure arises.*

Proposition 2 provides a qualification of the tax spinning hypothesis. The informal literature argued that $p < p^a$ constitutes the necessary and sufficient condition for tax spinning to be a profitable action in the

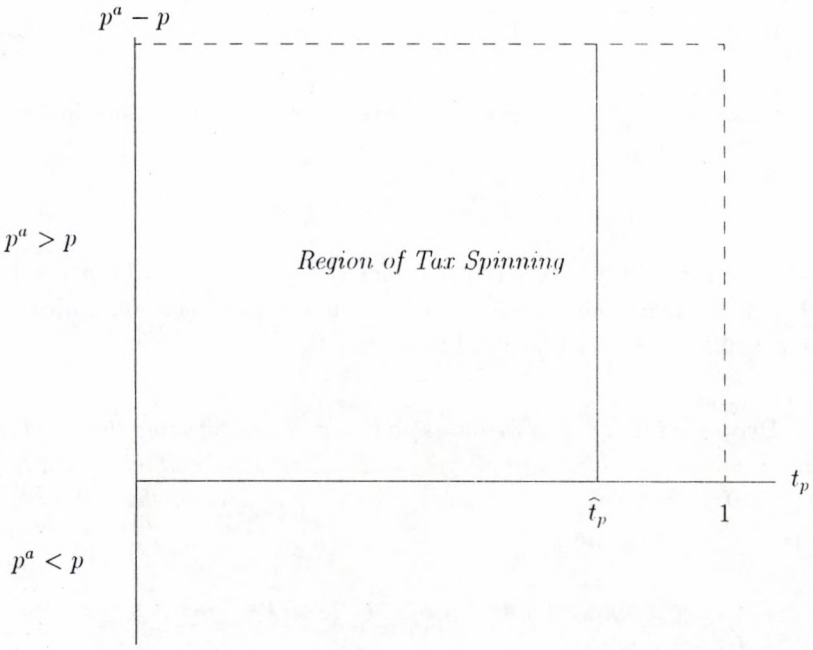

Figure 1: **Region of Tax Spinning Hypothesis**

absence of transaction costs. Figure 1 illustrates the conditions stated by the tax spinning hypothesis for spinning to be profitable. The dashed area represents the region in which tax spinning is allegedly profitable. The introduction of strategic interaction in the refining industry further restricts the parameter space allowing for vertical supply. For an illustration, assume the following numerical values for (43): $p^a = 10$, $\widehat{p} = 5$. For vertical supply to arise in equilibrium, (10) requires that $z > 5$. Suppose now that $z > p^a$, i.e. $z = 11$. Then $\Upsilon > 0$ in (43) would imply $t_p > 6/5$, which is impossible. If $z < p^a$, say $z = 7$, $\Upsilon > 0$ were equivalent to $t_p > 3/5 = \widehat{t}_p$. For this case, vertical supply depends on the actual PRT–rate exceeding the threshold value of 3/5. It is easy to see that if z is in the neighbourhood of $\widehat{p}$, $\widehat{t}_p$ is rather small (for $z = 11/2$, $\widehat{t}_p = 1/10$), and that if z is near p^a, $\widehat{t}_p$ is rather high ($z = 9$, $\widehat{t}_p = 4/5$). Figure 2 illustrates the scope of vertical supply (tax spinning) in the strategic setting. The dashed area illustrates the conditions that are behind vertical supply according to Proposition 2.

The conditions under which vertical supply arises in equilibrium are much more restricted conditions than was claimed by the informal spinning hypothesis. The sufficient condition has no counterpart in Mabro et al.'s (1986) argumentation, and Proposition 2 shows that the tax price and the PRT-rate must strictly remain above some lower floors for vertical supply to be profitable.

An obvious question arises whether the tax price p^a can ever exceed the refined products price z. A priori, under the institutional setting of section 5 there exists no reason why the tax price should not, in certain periods, exceed the refined products prices. Ideally, p^a should reflect the market price of deals and commodities similar to the transfers of crude oil within the integrated firm. In practice, however, it was an administered price posted by the British National Oil Company (BNOC) for the purchase of participation crude and determined through bargaining between the BNOC and its sellers and buyers. As every adjustment of the tax price had to pass through an institutionalised bargaining process of price formation, it is unlikely that the tax price adjustment to changing crude oil market conditions could have proceeded in an instantaneous manner.

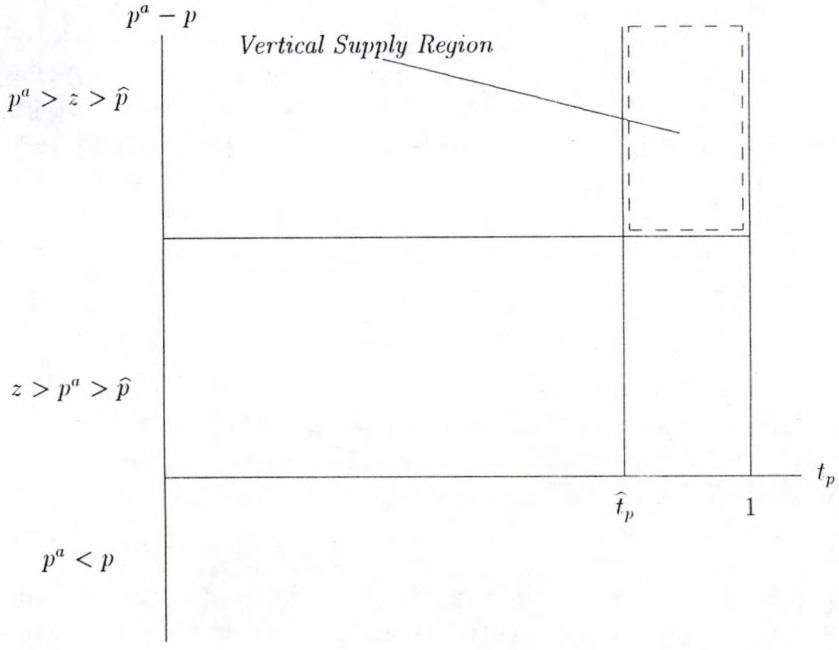

Figure 2: **Region of the Vertical Supply Hypothesis**

If the spot and subsequently the refined products price fall sharply,[21] and the term or tax price reacts only with some delay, circumstances might arise where $p^a > z$, thereby creating a temporary incentive for vertical supply. Mabro et al. observe a similar pattern in their analysis of episodes of tax spinning:

> In each case the episode began with a sharp fall in spot price, creating an incentive to spin; and in four cases the episode ended with a price cut by BNOC (1986:127).

Under the new institutional regime yet to described in section 6, the tax price is defined as the average of prices realized in spot and forward deals nominated during a well–specified time period, which might even involve some future dates. Now suppose that after a period of high crude oil and refined product prices the crude oil price and products price drops. The average of high price deals nominated previously reacts only sluggishly at the further addition of a lower priced deal. If the oil firm has to make a decision towards the end of the nomination period so that expected prices of future deals play a minor role, it is perfectly imaginable that the average of prices, i.e. p^a, exceeds the current lower refined products price z.

Tax Policy and Vertical Foreclosure Two parameters are crucial for the integrated firm's incentive to foreclose its rival: the tax price p^a and the PRT–rate t_p. Under both the old institutional regime and the new one, although the tax policy makers can define p^a, they cannot "fine–tune" it to reach some policy targets. This leaves t_p as the parameter that can be controlled to influence vertical supply relationships. I argue that the discretionary policy of the UK tax authorities has provided incentives for vertical supply. Ever since the implementation of the Oil Taxation Act 1975, tax spinning or vertical supply has been possible for integrated oil firms. According to Mabro et al. (1986), the first public reporting of tax spinning dates back to April 1981, when Conoco and BP first started

[21] A reduction in p is accompanied by a reduction in z, since $z'X_p > 0$ (see 21).

this tax optimisation exercise. The story told by Mabro et al. why tax spinning was not perceived earlier than 1981 begins with the Iranian oil crisis of 1978/9.[22] In its wake, long–term supply contracts were broken and for oil firms and traders, looking for new trading tactics and sources of oil, the Brent market became attractive. As of January 1981, short selling of Brent crude was reported for the first time, a strategy that became feasible because the integrated oil firms were selling part of their crude oil production into the spot market for tax reasons. Since then, it is said, tax spinning was practiced whenever the conditions for it were right, which of course is usually meant to refer to the informal hypothesis' condition of a positive differential $p^a - p$. This story, however, is incomplete. It leaves out the crucial role of the PRT–rate. Table 1 shows for the years 1978–1980 a substantial increase of t_p of around 55 %. This increase in the PRT–rate preceded the first publicly reported occurrence of sales of crude oil by integrated companies as of the beginning of 1981. By then, the PRT–rate t_p was as high as 70 %, compared to 45 % the years before 1978. Proposition 2 suggests that, even if the market conditions were favourable for spinning in terms of the "correct" sign of the price differentials ($p^a > z > \widehat{p}$), vertical supply did not emerge before 1981 simply because the PRT–rate was *too low* to make this practice profitable. After the increase of the PRT–rate, it was high enough to make vertical supply profitable, if the necessary and the sufficient conditions were met. By the same token, the reduction of the PRT–rate from 75 % in 1992 to 50 % in 1993 might mark the end of the traditional tax spinning game.

6 Spinning Under Tax Price Uncertainty And Endogeneity

Recent changes in the UK oil taxation regime have introduced further restrictions into the tax–spinning game between the oil companies and internal revenue. These changes extend to questions of the method of *valuation* and *nomination.*

[22] See Cremer and Isfahani (1991) for an account of world oil trade and prices during the 20th century.

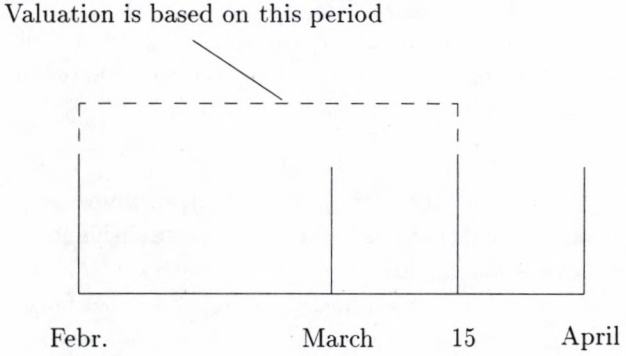

Figure 3: **Nomination Period**

Valuation For the valuation of output disposed of in a non-arm's length deal, i.e. through an internal transfer from upstream to downstream units of an integrated company, the U.K. Oil Taxation Office (OTO) has until 1984 considered the contemporary BNOC term price as the artificial market reference price for such transactions. In 1984, the OTO considered the BNOC term price to be no longer representative. After an interim period that created ambiguity about valuation for fiscal purposes, the tax authority eventually introduced a new method in 1987 (see Horsnell and Mabro 1993). The new method defines the *assessed market value of internally disposed crude as the average of realized prices of spot and forward sales of crude oil.* The sales contracts that form the base on which this average is computed are defined on a *temporal basis*: "The relevant sales contracts ... are those entered upon within the period beginning at the start of the previous month and ending on the middle day of the month in question" (Horsnell and Mabro 1993, p. 63).

Consider the period from February to April, showed in Figure 3. The "problem" for the OTO is to assess a value for PRT purposes to all barrels of crude oil transferred within integrated companies in March. March is then "the month in question". The valuation of internally trans-

ferred March crude is based on the *average* of prices established in spot sales and forward contracts for *March delivery* during the period between the first of February and the 15 of March, see Figure 3.

Nomination In the game–theoretic model discusses above, the procedure of nomination of contracts for sales in order to establish a market price for PRT purposes was straightforward. In line with the practice until March 1987, the integrated firm was able to freely optimise by choosing the amount of crude transferred internally or sold in an open market transaction. This freedom in principle extended also to the choice which forward deals should become wet, but since the model abstracts from forward trading, this problem remains without further consideration. As of March 1987, a nomination scheme was introduced by OTO putting a rigid constraint on the tax optimisation game played by the integrated oil firms. The procedure requires that each upstream producer should nominate a sales transaction for PRT purposes within a well-defined nomination window with a length of two days or four days when there is an intervening week-end. Following a prolonged review of North Sea oil trade by the UK tax authorities, recent British budget proposals imply a further tightening of the nomination window. As of January 1st, 1994, the time allowed for nominating equity sales is reduced from 48 hours to 24 hours. The tightening of the nomination window is expected to yield an extra fiscal revenue of about £5mn a year.[23]

If a producer's nominations to OTO for a given months exceed its total production, i.e. there are no internal transfers,[24] than the most recent nominations are cancelled until nominated and actual production are matched. If crude output is higher than nominations, this difference corresponds to a positive quantity of crude oil transferred internally and is taxed on the basis outlined above. Horsnell and Mabro (1993) stress that the new rules force firms to "take a view about future price movements in relation to the price of that deal when they consider whether they

[23]See Weekly Petroleum Argus WPA, December 6, 1993, for more information.

[24]This can happen if (i) crude oil produced and subsequently stored above the ground at Sullom Voe is now sold, or (ii) if a short forward position with delivery month later than the month in question is nominated.

should nominate or not"(p. 66). Moreover, "the oil company has no simultaneous knowledge of the actual market and the 'market valuation' (the tax price, A.S.) except on the last day of the trading period" (p. 67), which in the example discusses above would be the 15th of March. Since the quality of the forecast of the uncertain tax price improves during the six-week period, the nominating producer would prefer to postpone all decisions towards the end of this period, which, is not possible given lifting, refining, and production constraints. Hence, for a company being somewhere between February 1 and March 15, expectations about the ex-post computed average price for that very period on which valuation is based have to be formed.

Tax Spinning Are the changes in oil taxation outlines in the preceding sections substantial, i.e. do they impact on the incentives of the integrated firm to supply crude to its downstream rival? If a vertically integrated company were only considering tax incentives in its crude supply decision, as is repeatedly suggested by the informal literature,

> (...) it will pay the vertically–integrated oil company to sell its oil arm's length whenever it expects the realized market price to be lower than the OTO's valuation of a non–arm's length deal; and to appropriate the oil whenever it expects the realized market price to be higher than the OTO price. In both cases the vertically–integrated oil company chooses to make less pre–tax profits upstream but this is exactly compensated for by higher pre–tax profits downstream. There is an overall gain in after–tax profits since the tax rate is lower downstream than upstream. (Horsnell and Mabro 1993, . 63).

Does this new condition changes the qualitative results derived for the integrated firm's behaviour *at the foreclosure margin*? To answer this question, consider that the use of the expectations operator indicates that future price movements are perceived as uncertain by the spinning firm. Horsnell and Mabro (1993) argue convincingly that tax spinning practices now are based on ex–ante guesses and expectations of future price and that therefore

> (...) the number of physical cargoes (given the level of production) that will be made available to third parties is likely to vary depending on the expectations of integrated companies as regards the direction of price changes during each six–week computation period (p. 68).

The most important impact these policy changes have is on the nature of the tax price p^a. It is now an endogenous variable. First, it depends on expectations formed by the integrated oil firm about future prices; and second, it is based on an average of prices agreed upon in spot or forward contracts that have been entered by the nominating integrated oil firm. In formal terms, define the expectation of a crude price in period j as of time t, where $j > t$, as $E_j[p_j|t]$. The endogenous tax price, computed over the whole six–week period (or two week period, if only spot sales are considered) is now defined as the average value of realized *and* expected arm's length prices of nominated deals (= total production of firm v) :

$$p^a := A(p,t) = \frac{1}{T}\left[\sum_{i=1}^{t} p_i + \sum_{j=t+1}^{T} E_j[p_j|t]\right], \quad i = 1,...,t \quad j = t+1,...,T. \tag{45}$$

The endogenous tax price has the following "degenerate" cases:

$$A(p,t) = \begin{cases} A(p,0) = \frac{1}{T}\sum_{j=1}^{T} E_j[p_j|0] & \text{if} \quad t = 0 \\ A(p,T) = \frac{1}{T}\sum_{i=1}^{T} p_i & \text{if} \quad t = T \end{cases}. \tag{46}$$

The first case for $t = 0$ defines the tax price as a complete expectational term. Such is the situation for an integrated oil firm at the morning of the first of February, where T stands for the 15th of March and where it possesses no information about the price path yet to arise over the six–period horizon. The second degenerate case describes the situation for the firm at $t = T$, when it has simultaneous knowledge of $A(p,T)$ and p_T. Expectations do not have to formed at this decision point. The necessary and sufficient condition for tax spinning to arise at a certain point in time t according to Horsnell and Mabro becomes

$$p_t < A(p,t), \qquad t \in [1,T]. \tag{47}$$

It is safe to assume that the nomination window closes at the end of the day of the sales (recall the 24 hours window) and that all external sales are nominated for PRT purposes.[25] Then, subscript t denotes the day on which the produced crude output has either to be sold on the market or internally transferred. Since only spot sales are explicitly analysed, and spot contracts call for immediate delivery, spot contracts for March delivery could only be made in March.

Proposition 3 *Suppose the following set of assumptions hold:*

1. *The integrated firm is risk–neutral, i.e. its utility function is linear in profits;*

2. *The impact of a small change of p at the foreclosure point, dp, has no impact on the average of prices of deals nominated before t, $\frac{1}{t}\sum_{i=1}^{t} p_i$.*

3. *The formation of expectations is exogenous.*

Given assumptions 1. -3., the integrated firm's foreclosure versus supply decision is not affected by the new tax policy rules. Proposition 2 holds, with $p^a := A(p,t)$.

Proof By assumption 1, actual values are merely replaced by their expected values in the profit function (30). By assumption 2 and 3, $A(p,t)$ appears in the first–order condition (31) and the successive equations as a completely exogenous variable, in perfect correspondence to the role of p^a.

[25]Since the model treats cargoes of Brent as being traded only once, and since no other reason exists for cargoes to be disposed of externally than for tax spinning, this assumption amounts to a logical derivation.

7 Conclusions

In a two–stage game where the integrated producer acts first by credibly committing itself to a crude oil price that constitutes the input cost for an unintegrated downstream rival, and where the second stage is a Cournot game between the integrated firm and the unintegrated rival, vertical foreclosure is the equilibrium outcome if there were no taxes (Proposition 1). Under the UK tax regime, vertical supply arises when the tax price is greater than the refined products price that in turn must exceed the foreclosure price *and* if the PRT–rate is high enough so as to exceed a certain threshold level (Proposition 2). Proposition 3 shows that the recent introduction of new rules concerning crude oil valuation and nomination of deals for tax purposes does not affect the underlying incentives to supply or foreclose the crude oil market at the foreclosure margin. The analysis shows that the conditions behind vertical supply are more restrictive than the informal tax spinning hypothesis has claimed. According to the latter, a positive differential between the tax price and the crude price would be necessary and sufficient for tax spinning to become profitable. Both the tax spinning hypothesis and Proposition 2 point in the same direction concerning the "right market conditions" for tax spinning to arise. Episodes where the tax price exceeds the crude (foreclosure) price are likely to be episodes where the tax price also exceeds the refined products price. The spinning hypothesis has, however, paid no attention to the role of the PRT–rate to provide proper incentives for vertical supply. It is argued that the substantial increase in the PRT–rate during the period 1978-1980 made spinning profitable for the first time. By the same token, the reduction in the rate from 75 % in 1992 to 50 % in 1993 might have brought the rate down below the threshold level above which vertical supply becomes profitable. Since tax spinning is considered to be a major drive behind the crude oil trading of the integrated firms, the recent tax policy changes might jeopardize the liquidity of the Brent market.

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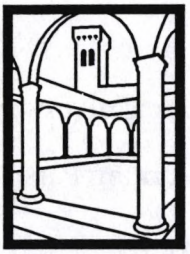

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